ABSTRACT

The present work concerns fundamental studies with (a) thermal nanofluid to explore the possibility of utilizing the same in emergency core cooling systems (ECCS) of nuclear reactors and (b) magnetic nanofluid (or ferrofluids) to investigate the scope of applying the latter for droplet based microfluidic applications, respectively. The investigations using thermal nanofluids involves the preparation and characterization of nanofluids, study of Leidenfrost phenomenon of nanofluid droplets and rewetting phenomenon of vertical tubes by bottom flooding. Magnetic nanofluids are synthesized by chemical method and actuated over an inclined hydrophobic substrate by an externally applied magnetic field.

In ECCS designed for nuclear reactor cores, rewetting phenomenon plays a crucial role in determining the efficiency of the cooling process. Since, rewetting and Leidenfrost phenomena are very closely related, both are investigated to understand the physics controlling the processes. Water as a coolant is used as a benchmark for comparison and establishing the level of improvement. The evaporation rate of titania (TiO_2) dispersed nanofluids is faster than that of water which increases with the increase in concentration of nanoparticles. The Leidenfrost temperature is augmented significantly for nanofluids in comparison to water. The ejection of tiny droplets governed by the vapor jet velocity during the Leidenfrost phenomenon controls the post dry-out heat transfer (dispersed flow) during rewetting by bottom flooding. The cooling rates of alumina (Al_2O_3) nanofluids during rewetting is considerably higher than water and dependent on the concentration of nanoparticles, coolant flowrate and initial tube temperature. The fluid flow and heat transfer mechanisms are analyzed from the visualization of the quench front and estimation of the boiling curves, respectively. In both the phenomena, the deposition of nanoparticles controls the dynamics of the vapor layer collapse.

Magnetite (Fe_3O_4) dispersed ferrofluids are prepared and characterized with a special emphasis on the rheological properties in presence of magnetic field. The effective modulation of viscosity by altering the confinement geometry in the presence magnetic field have an important bearing on the design and operation in microfluidics. Ferrofluid droplets are actuated over an inclined substrate by a moving magnet of sufficient strength. The trapping of the droplet by the magnet is favorable when the applied strength and concentration of nanoparticles is high and velocity of the magnet is moderate. Under suitable conditions, the droplets undergo distortion and tearing – famously known as pearling – the mechanisms of which are established through this study.